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HEART DISEASE AND PREGNANCY*

The subject of heart disease and pregnancy was reviewed in *Modern Concepts* by Dr. Julius Jensen in 1949. In the five-year period since then, several advances in medicine have led to better understanding and better management of pregnant women with heart disease. These advances include the following:

1. Increase in knowledge of the physiological adjustments to pregnancy and the interactions of pregnancy with disease.
2. Increased appreciation of the effect of sodium restriction in the prevention and treatment of congestive heart failure.
3. Increased knowledge of the effect of antibiotics on subacute bacterial endocarditis as well as an increase in the power and diversity of available antibiotics.
4. Further development of surgical methods for the treatment of mitral stenosis and of certain forms of congenital heart disease.

The authors' knowledge of the problems of heart disease in pregnancy comes from two varieties of experience: first, studies of the physiology of pregnant women, and, second, a growing experience with the medical problems of pregnant women in the medical clinic of the Boston Lying-in Hospital.

A useful guiding principle in the study and care of disease in pregnant women is the following:

The physiological mechanisms of disease interact with the physiological mechanisms of pregnancy. To understand and to manage disease in pregnancy, it is necessary to understand these two sets of mechanisms and their interactions.

CIRCULATORY CHANGES IN PREGNANCY

The maternal organism provides the fetus with the environment and the material required for his development. To this end, changes occur in the maternal organs and tissues. A number of these changes involve the cardiovascular system

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and may influence the course, the manifestations, and the management of cardiac disease. Some of the relevant adjustments to pregnancy in the mother's machinery are as follows:

1. *Oxygen consumption.* Part of the metabolic price of pregnancy is reflected in an increase in the oxygen absorption of the mother. Oxygen consumption rises progressively throughout pregnancy, with the largest increase during the last trimester. Under scrupulous basal conditions the rise amounts to a maximum of about 20 per cent above the non-pregnant level. Most of this increased oxygen is consumed by the tissues of the fetus and the uterus. The mother's heart has the responsibility of providing the uterus and its contents with oxygen by way of the maternal uterine circulation.

2. *The heart rate.* There is a rise in heart rate early in pregnancy. This rise attains a maximum at about the eighth month. In the last weeks of pregnancy the heart rate is somewhat lower than at this maximum. In the latter part of pregnancy the increase amounts to about ten beats per minute. This may seem trifling, but it amounts to 14,000 extra heart beats per day.

3. *The cardiac output.* The cardiac output has been shown by a number of methods in various laboratories to increase during pregnancy. This increase is out of proportion to the increase of oxygen consumption and may amount to 40 or 50 per cent, with a maximum about the eighth month and a return toward the normal level in the last weeks of pregnancy. This increase is present day and night. Although it is borne without symptoms by the normal heart, this burden may cause disability in patients with heart disease. A considerable proportion of this extra blood flow is distributed to the placenta and the uterus. It appears that an increase in cardiac output is essential for the adequate irrigation of the placenta. There is some increase in blood flow through certain parts of the mother's periphery, notably her hands. This seems to be a mechanism by which the mother rids herself and her fetus of the heat produced by his active metabolism.

4. *Blood volume.* During pregnancy the total blood volume increases, and this increase may be of the general order of 30-50 per cent. The in-

crease of the plasma volume exceeds that of the red cell volume, so that the hematocrit falls. The curve of blood volume, like that of the cardiac output, reaches its highest point in the seventh or eighth month and tends to diminish as term approaches.

5. *Ventilation and lung volume.* The ventilation per minute is elevated, and this increase in volume of ventilation is greater than the increase in the total oxygen consumption. This disproportion indicates that pregnant women hyperventilate during pregnancy, a fact which is substantiated by the observation that there is a lowering of the partial pressure of CO_2 in the alveolar air and arterial blood of pregnant women.

Pregnancy in itself does not cause a decrease in vital capacity. On the contrary, it has been shown that the inspiratory capacity is increased more than enough to compensate for an observed decrease in expiratory reserve. Thus the sum of these volumes, the vital capacity, is usually increased during pregnancy. The usual increase in vital capacity occurs at the expense of the residual lung volume. That the vital capacity is maintained or even increased during pregnancy is a useful fact. It means that when reduction in this function is observed during pregnancy, it is not to be explained by the pregnancy itself but must be due to something else.

6. *The blood pressure.* The arterial blood pressure is not greatly altered during pregnancy, although there is some tendency for a fall in the diastolic pressure and a widening of the pulse pressure. The venous blood pressure in the arms is within normal limits. The venous blood pressure in the legs is elevated although in non-pregnant women it is identical in arm and leg. This suggests that part of the increased blood volume in pregnant women is held in the leg vessels.

These changes in the oxygen consumption, heart rate, blood pressures, blood volume, ventilation, and lung volumes are some of the quantitative physiological alterations associated with pregnancy. Knowledge of the changes mentioned can be applied directly to the management of heart disease in pregnant women. These changes which are due to pregnancy itself do not constitute the only problems for the maternal heart. There is another set of alterations in the circulation which occur during labor when the oxygen consumption has a further rise and when there may be striking changes in the heart rate. It will be remembered that these come at a time when diminution in the cardiac output has already occurred, so that the heart has a certain amount of additional reserve.

CHANGES IN THE CIRCULATION IN CARDIAC PATIENTS

The various changes in the circulation of pregnant women, as described in the first section of this paper, influence both the diagnosis and the management of heart disease in these women.

Pregnancy produces alterations in heart sounds and in murmurs, so that a given lesion may be more impressive and more easily recognized in a pregnant woman than in the same woman when she is not pregnant. Pregnant women tend to have arrhythmias, particularly paroxysmal auricular tachycardia, more frequently than non-pregnant women; and pregnancy, by changes in the ventilation pattern, increases the ease with which pregnant women with heart disease develop dyspnea. The effects of pregnancy on the manifestations of heart disease may be either helpful or deceptive. We prefer to appraise the severity of a given cardiac lesion by observing the patient both during pregnancy and postpartum.

It is easy to over-diagnose heart disease in pregnant women, and it should be kept firmly in mind that systolic murmurs and alterations in heart sounds are often due to the changes in the circulation associated with pregnancy and need not be due to disease.

In four years of experience on the medical service of the Boston Lying-in Hospital we have seen through pregnancy approximately 300 women with important cardiac disease. Nearly 90 per cent of these have had rheumatic heart disease and most of the remainder have had congenital heart disease. Two-thirds of the whole group have had mitral stenosis as the major lesion. This lesion is, therefore, selected as an example of heart disease in pregnancy. The pathologic physiology of mitral stenosis has been clarified by Dexter and his colleagues. Briefly, in mitral stenosis the mitral orifice is reduced in size and its area may measure no more than one-tenth of normal. This reduction in the area of the valve orifice imposes an obstruction to the flow of blood, and this obstruction produces changes in the circulation. Cardiac output will fall unless left auricular pressure rises. The human organism, experienced in meeting difficult situations, handles this one with a compromise. The left auricular pressure rises somewhat, but usually not enough to maintain cardiac output. In those patients with significant but lesser degrees of mitral stenosis whose resting cardiac output is normal, the rise in cardiac output during activity is less than normal. This relationship between left auricular pressure and the flow through the mitral valve means that an increase in cardiac output requires a further rise in left auricular pressure. A rise in left auricular pressure is necessarily followed by a corresponding rise in pulmonary capillary pressure.

Forward flow through the mitral valve can take place only in diastole. In the normal person only a small part of the available diastolic time is needed for even large volumes of blood flow. In the patient with severe mitral stenosis, on the other hand, much or all of the available diastolic time is used for the flow of blood through the narrow valve. When the heart rate rises, the available diastolic time is reduced; therefore, patients with mitral stenosis often bear tachycardia badly.

THE COMBINED EFFECTS OF PREGNANCY AND HEART DISEASE

Consider now the effects of pregnancy on the dynamics of mitral stenosis. Pregnancy in women with heart disease, as well as in normal women, is accompanied by a rise in cardiac output. Such a rise requires an increase in the rate of blood flow through the mitral valve. In patients with mitral stenosis, such an increase in flow requires an increase in left auricular pressure. This leads in turn to an inescapable increase in pulmonary capillary pressure and thereby places the pregnant woman with mitral stenosis closer to pulmonary edema than when she is not pregnant. The tachycardia of pregnancy and particularly the increased blood volume of pregnancy may also lead to elevation of atrial and capillary pressures and, therefore, to the precipitation of disability.

THE MANAGEMENT OF THE PREGNANT CARDIAC

In managing heart disease in pregnant women, the major principle is to organize ways and means which limit or restrict the rise in cardiac output, cardiac rate, and total blood volume. The physician concerned with these patients must deal with the total sum of factors that influence output, rate, and volume and, therefore, determine the total cardiac load which results from the patient's total situation, including her pregnancy. One attempts to make a place in the patient's cardiac budget for the expenditures required by pregnancy by eliminating equivalent amounts of other expenditures. It is therefore necessary to consider various factors which increase the cardiac load and which have the further essential characteristic that they can be controlled. The objective is not necessarily to keep the total load at an absolute minimum but to keep it safely within the individual patient's tolerance.

Individual factors in patients' lives which lead to increase in heart rate, cardiac output, or blood volume include: (1) *Physical activity*, (2) *Emotional stress*, (3) *Ectopic rhythms with tachycardia*, (4) *Anemia*, (5) *Obesity*, (6) *Infections*, (7) *Hyperthyroidism*, (8) *Infusions or transfusions*, which, by their effects on the blood volume, may influence the course of pregnant women with heart disease. Such sudden increase in blood volume has been known to precipitate pulmonary edema. (9) *Variation in sodium intake or retention*. The physiological control of blood volume is not simple and is especially complex in pregnancy. Certain factors which influence it can be identified and used, and the regulation of sodium intake is the important example. In our opinion, the most useful recent addition to our capacity to control the disability of heart disease in pregnancy has been the increasing knowledge of the effectiveness of sodium restriction.

This regulation of controllable factors in the

total load on the heart of pregnant women is to be carried out with due consideration of the predictable variation in the load of pregnancy itself. We can use our knowledge of the curve of cardiac work in pregnancy. We can plan to exercise the most rigid control at the time of maximum load in the seventh or eighth month, and we can expect improvement in cardiac symptoms during the final weeks of pregnancy. Hamilton pointed out many years ago that the incidence of congestive phenomena in pregnant patients with heart disease follows closely the curves of cardiac output and blood volume.

In the vast majority of cases the application of these principles to the management of pregnant women with heart disease will permit them to go through pregnancy safely and to produce a living baby. Occasionally such regulation is not enough and the continuation of pregnancy appears to be dangerous to the life or health of the mother. In such cases, it may be necessary to consider the radical treatment of heart disease in pregnancy either by the termination of the pregnancy or by an operative attack on the major cardiac lesion. The necessity for termination of pregnancy is fortunately rare and getting rarer, but even with our improved ability to deal with these problems it is still sometimes a necessity if the mother's life and health are to be protected. The decision to terminate must be made early in pregnancy for two reasons: (1) The hazards of operation are progressively greater as pregnancy advances; (2) the cardiac reserve diminishes as the burden of pregnancy increases. The decision to terminate must be made only after a careful appraisal of all the problems involved. The severity of the heart disease, the age of the patient, the occurrence or history of heart failure, the presence of severe arrhythmias, the existence of other disabling disorders, the possibility of adequate supervision and accurate management must all be taken into consideration.

SURGICAL TREATMENT OF MITRAL STENOSIS DURING PREGNANCY

As to the possibility of the surgical treatment of mitral stenosis during pregnancy, the following observations reflect our current view of this problem.

Mitral stenosis is the main cardiac problem in pregnant women. The trouble with these people is that the valve opening is too small. Appropriate surgical procedure can enlarge this opening; therefore, it is necessary to consider the application of mitral surgery to the management of pregnant women with heart disease.

It is early in the developing history of mitral valve surgery. Policies must now be tentative and they must be developed with due consideration of the special problems presented by the pregnant woman. Our experience to date has led to certain tentative conclusions. They are as follows:

1. Women with mitral stenosis and pregnancy on the whole do well with informed medical treatment.

2. In many instances pregnant women with mitral stenosis can undergo an operation on the mitral valve and continue the pregnancy to a successful conclusion. Most of these women would probably do well without an operation if the medical supervision was adequate.

3. The total situation in pregnancy is more complicated than when the same patient is non-pregnant, and, therefore, the operation can be expected to carry a higher hazard.

4. There may be reactivation of rheumatic fever after mitral valve surgery.

5. The history of mitral surgery over recent years has shown that it is not always possible to evaluate the degree and importance of mitral stenosis preoperatively. *In any hands the diagnosis may be wrong.* We have seen two patients subjected to valvuloplasty during pregnancy in whom the extent of mitral regurgitation had been underestimated. When regurgitation turned out to be the main problem, these women had been subjected to a formidable operative procedure without improvement in cardiac function. Both required termination of pregnancy later; one survived after a long illness; one died.

Therefore, it is our opinion that mitral valve surgery during pregnancy should be recommended only in rare and special cases. These will be individuals who have important and stubborn congestive phenomena in their pregnancy or who did badly in previous pregnancies with good medical management. They will be patients in whom it can be shown that ideal medical management is not effective, and in our opinion they should be patients in whom the safer procedure of interruption is not practicable.

Operation on the valve during pregnancy is usually *not* the best way to handle the problem of mitral stenosis. But we believe that there is a relation between pregnancy and mitral surgery more important than operation during pregnancy. A medical clinic in an obstetrical unit can be an effective case-finding agency. About half of our patients with rheumatic heart disease were not aware of its existence until they were studied in the medical clinic. The effectiveness in case-finding of such a clinic is partly due to the effect of pregnancy in making the signs of heart disease more obvious. Murmurs that are impressive during pregnancy may become minimal or even disappear after delivery. Two conclusions follow: (1) Pregnancy helps diagnose the fact of the existence of heart disease. (2) The appraisal of the severity of mitral stenosis or other valvular disorder and a decision about the need of surgery is best made when pregnancy is completed and the patient has been observed in the non-pregnant state. On the double basis of observation during pregnancy and reappraisal postpartum, a considerable group of our patients with mitral stenosis

have undergone valvuloplasty after successfully completing pregnancy. They have done well. Several women whose pregnancies were interrupted because of mitral stenosis have been referred for surgery afterwards and had good results. A small number have gone through a subsequent pregnancy, obviously better able to deal with it than before operation. This, in our opinion, is the best way to use mitral surgery in relation to pregnancy. These results are so good that *mitral stenosis requiring the interruption of pregnancy is no longer an indication for sterilization.*

CONGENITAL HEART DISEASE

Congenital heart disease is not a rare problem in the pregnant woman and has been managed in basically the same manner outlined above for rheumatic valvular disease. Some special aspects should be mentioned. There is reason to believe that the physical characteristics of the aortic wall change during pregnancy. This is suggested by the frequent X-ray finding of aortic shadow enlargement during pregnancy and the reported occurrence of dissection of the aorta in pregnant women. For this reason we would advise delaying operation for coarctation of the aorta until after pregnancy had been completed.

In the literature on this subject disability is rare in pregnant patients with patent ductus arteriosus. In the one case we have followed through pregnancy with an unligated ductus, operative closure was successfully carried out 6 months postpartum.

Our experience with congenital heart disease also includes patients with congenital pulmonic stenosis, interventricular septal defect, and interatrial septal defect. All have progressed uneventfully through pregnancy. It must be emphasized that each patient is evaluated and managed as an individual problem.

SUBACUTE BACTERIAL ENDOCARDITIS

The incidence of bacteremia during labor and the postpartum period is unknown, but a significant incidence of subacute bacterial endocarditis has been reported in postpartum women. On this evidence all patients with rheumatic or congenital heart disease are given penicillin prophylactically during labor and for three days following delivery. We have not seen a case of subacute bacterial endocarditis in the postpartum period when this regimen has been used.

ACUTE RHEUMATIC FEVER

Although acute rheumatic fever is a rare occurrence during pregnancy, it does occur in cardiac patients after delivery. For this reason we have recently employed prophylactic oral penicillin in the postpartum period. With advancing experience the number of patients placed on the

regimen is being increased. Furthermore, evidence is accumulating that acute rheumatic fever without overt manifestations can occur in patients with rheumatic heart disease. Therefore, we are beginning to give oral penicillin during pregnancy to young patients with rheumatic heart disease and to those with recent acute rheumatic fever. This is continued after delivery.

Application of the principles discussed above has been rewarding in our experience. Over 300 patients with heart disease have been seen during pregnancy. Twenty-three of these have had their pregnancies interrupted because of the severity of their heart disease while 277 have gone through their pregnancies. In the last 100 pregnancies in cardiac patients only two have been interrupted. Six patients have had mitral valvuloplasty during pregnancy. Two of these have died. One patient died suddenly after interruption. No woman followed with conservative medical management has died during pregnancy or in the postpartum period.

LABOR AND DELIVERY

To bring women with heart disease through pregnancy and up to term in good order and free of congestion is the chief contribution the physician can make to the delivery. Skillfully organized and executed delivery is a vital matter to these patients, and while continued close cooperation between the obstetrician and the physician is essential, the obstetrician here plays the decisive role. The decrease in cardiac output and blood volume during the final weeks of pregnancy provides the patient with a growing margin of

reserve which usually suffices to meet the demands of labor. Our obstetrical colleagues have shown us that ether anesthesia is well tolerated by these patients, and advocate the use of low forceps to shorten the second stage of labor. Unless there are obstetrical indications, Caesarean section is not recommended for patients with heart disease.

SUMMARY

An understanding of the physiological changes occurring in the circulatory system during pregnancy and the changes in the circulation caused by heart disease makes possible an integrated approach to the management of the pregnant woman with heart disease.

Medical management based on these principles has been successful in bringing the vast majority of cardiacs through pregnancy.

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* This work was done during the tenure of an Established Investigatorship of the American Heart Association.

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